INL's Strategic Initiatives

NUCLEAR REACTOR SUSTAINMENT AND EXPANDED DEPLOYMENT

The baseload power provided by nuclear reactors is essential to the world's integrated low-carbon energy future. Today, 10% of the world's electricity comes from 450 power reactors, and many of those are aging. To meet the growing demand for sustainable energy, nuclear power generation must triple by 2050 to provide 25% of a clean and reliable low-carbon mix. Because the addition of new nuclear energy systems will take time, it is also essential to sustain the current fleet to facilitate continued safe and economical operations in the interim. INL uses its unique combination of world-class RD&D experience, infrastructure assets, and partnership relationships to address the most difficult technical and operational challenges of the existing fleet, advanced fuels, and advanced reactor design and demonstration to sustain the existing fleet and expand deployment of nuclear energy in the future. INL anticipates deploying new demonstration and test reactors regularly over the next ten years.

INL leads in creating and defining the next phase of global nuclear energy by driving technological innovations and operational advances through proof of concept, proof of performance, and proof of operations. These advances will further U.S. competitiveness and leadership in both the existing and the developing nuclear technology markets. INL's nuclear reactor sustainment and expanded deployment S&T initiative advances foundational science, at scale demonstrations, technology validation, and strategic partnerships to:

1. Strengthen the domestic commercial nuclear energy enterprise,
2. Enable U.S. technological leadership in global nuclear energy markets, and
3. Expand and deploy national nuclear energy strategic infrastructures.

INTEGRATED FUEL CYCLE SOLUTIONS

Integrated fuel cycle solutions are necessary for sustaining and expanding nuclear energy in the future. Redefining the nuclear fuel cycle, with an emphasis on cost-effectiveness and waste minimization, is essential to addressing the needs of an aging fleet and developing the next generation of reactors to sustain and expand nuclear energy deployment. INL's integrated fuel cycle solutions S&T initiative supports the safe, secure, and economical management of nuclear fuel from inception to disposition. To enable sustained and expanded nuclear energy through disruptive technology approaches, INL will develop the S&T and infrastructure to support:

1. Availability of special nuclear material (SNM),
2. Management of radiological waste materials and legacy fuels,
3. Reduction in proliferation risk, and
4. RD&D test beds.

The current U.S. nuclear fuel supply infrastructure is based on low enriched uranium (LEU) (i.e., less than 5% enrichment). Most of the advanced reactors of the future will require fuel with uranium that is enriched in U-235 in the 5–19.75% range and is commonly referred to as high-assay low-enriched uranium (HALEU). This transition necessitates a shift from a LEU to a HALEU fuel cycle infrastructure, but today the United States lacks domestic infrastructure and enrichment capacity to produce HALEU for the next generation of advanced reactor fuels.

INL is leading DOE efforts to support the development and deployment of the U.S. HALEU fuel cycle infrastructure. DOE sources of HALEU can bridge the initial gap between supply and demand but require further purification to meet fuel fabrication specifications. INL researchers have successfully completed the first experimental campaign to purify down-blended metal HALEU fuel originating from Experimental Breeder Reactor II (EBR-II) driver fuel. The purified HALEU was successfully produced in oxide forms suitable for use as feed stock for advanced reactor fuel fabrication.

ADVANCED MATERIALS AND MANUFACTURING FOR EXTREME ENVIRONMENTS

Nuclear, aerospace, transportation, defense systems, and other energy systems expose components to a variety of extreme or harsh environments, including high-radiation fields, temperature extremes, corrosive species, chemical containment, dynamic loading, mechanical impact, and both vacuum and high-pressure atmospheres. Advanced materials and manufacturing are needed to improve technologies deployed under these extreme conditions. INL's advanced materials and manufacturing for extreme environments S&T initiative accelerates discoveries and advances in materials for extreme environments, instrumentation, and energy technologies through adaptation, analysis, development, and integration of new or novel techniques.

Process-informed design departs from traditional approaches by leveraging scientific understanding of the influence of any given manufacturing process to design materials and components with targeted microstructures and performance characteristics. To advance the goals of the initiative, INL focuses on process-informed design for targeted performance and application-driven engineered materials and components within three interconnected focus areas:

1. Process discovery and development,
2. Secure digital design and manufacturing, and
3. Intensification and scale-up.

INTEGRATED ENERGY SYSTEMS

The integrated low-carbon energy systems of the future integrate diverse energy generation systems such as nuclear, geothermal, and other baseload sources, with intermittent renewables. From those energy generation sources, heat and electricity have traditional direct uses and the potential to support industrial processes, such as hydrogen production. To realize an optimized energy future, new integrated approaches to energy generation, storage, distribution, and use are needed. Nuclear energy is a proven low-emission option that can consistently meet electricity demands, and its potential value extends far beyond electricity generation. Without leveraging the full benefits of nuclear energy, the low-carbon energy systems of the future will unnecessarily operate with inefficiencies and will undervalue some methods and products of energy generation, delivery, storage, and use. To capitalize on the opportunities beyond baseload electricity generation and to expand the market for nuclear energy, INL's integrated energy systems S&T initiative leverages INL's core capabilities to develop and demonstrate multigeneration energy systems that, by incorporating nuclear energy with other forms of electricity generation, provide grid reliability, resilience, affordability, and new products.

The Laboratory's expertise in nuclear energy provides the basis to efficiently capture, distribute, and store nuclear-generated thermal energy for power generation or direct thermal-energy use. The integrated energy systems S&T initiative works to pave the way for eventual systems adoption by commercial producers and consumers through at-scale demonstration to make low-emission energy products economically viable across various energy markets. Integrated energy systems research is comprised of multiple focus areas working together to ensure technical feasibility, economic feasibility, and successful deployment. The integrated energy systems S&T initiative focuses on three primary areas of RD&D:

1. Thermal systems, including transport and storage of heat generated from nuclear reactors and other sources,

2. Electron systems, to manage an evolving electric grid and the electrification of the transportation system, and

3. Energy and elements-to-molecules and materials systems to develop novel approaches to capture and convert energy to molecules and materials for direct use in industrial processes and the transportation sector.

SECURE AND RESILIENT CYBER-PHYSICAL SYSTEMS

The cyber-physical systems integral to U.S. civilian and defense infrastructure depend upon transformational technological advancements that protect against the sophisticated capabilities of a global array of cyber-attackers. To secure these systems, solutions must holistically integrate traditional information assurance methods with the controllability, reliability, and safety of physical process effects, as well as manage the interdependencies and resilience of complex, engineered systems. Through the secure and resilient cyber-physical systems S&T initiative, INL develops new cyber-informed engineering methods and technologies for automated controls that are validated systematically at scale. INL's holistic approach, which incorporates technology, people, and processes, addresses the nation's most critical control systems cybersecurity challenges to secure and defend vital U.S. cyber-physical systems.

INL's background in nuclear energy RD&D provides robust expertise in the evolution of sensors and controls in critical systems. This expertise extends to the design of real-world experiments to verify models, construction and operation of demonstration pilot plants to validate engineering principles at industry scale, and integration of complex systems and facilities into interdependent infrastructures. By blending the resulting scientific and operations expertise and capabilities, INL is uniquely capable of interdisciplinary threat analysis and consequence-based risk prioritization to enable groundbreaking RD&D of unclassified and classified cyber-physical systems and the inherent embedded control systems integrated into power, communications, and defense systems. INL's efforts to advance secure and resilient cyber-physical systems center on three areas:

1. cyber-informed science and engineering,
2. all-hazard critical infrastructure, and
3. enduring control systems cybersecurity innovation.